Direct Relationship Between Perceptual and Motor Variability

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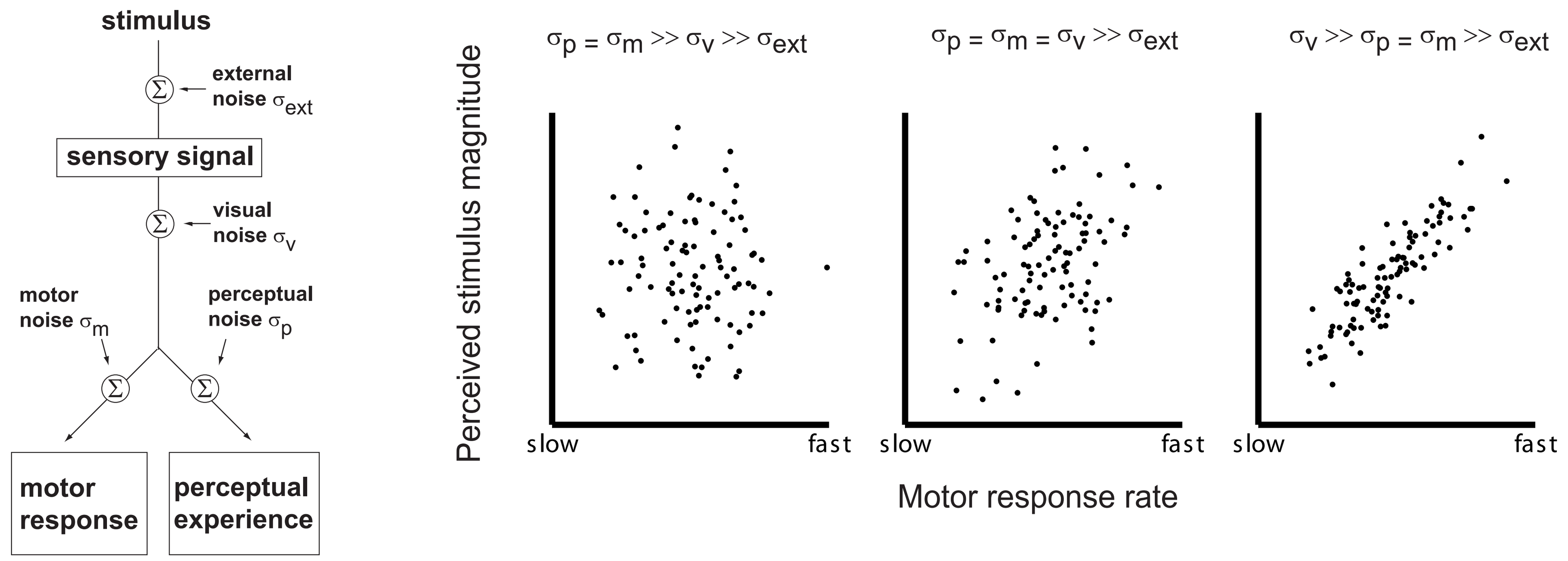
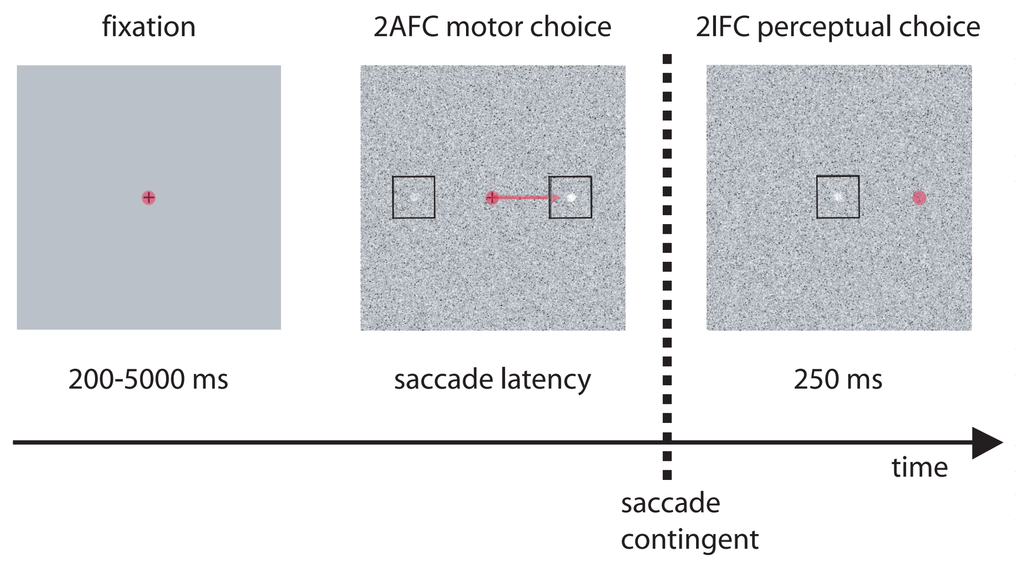
I. Introduction

The time that elapses between stimulus onset and the onset of a saccadic eye movement is longer and more variable than can be explained by neural transmission times and synaptic delays (Carpenter, 1981). In theory, factors underlying oculomotor response-time (RT) variability could arise at any point along the sensorimotor cascade, from early sensory noise (Green and Swets, 1966; Osborne et al., 2005) to noise in the motor criterion necessary to trigger a response (Grice, 1968). These alternative loci for internal noise can be distinguished empirically (Stone and Krauzlis, 2003). When shared visual internal noise dominates, saccadic response time will correlate with perceived stimulus magnitude whereas when unshared noise sources dominate, no such correlation will be observed.



II. Methods

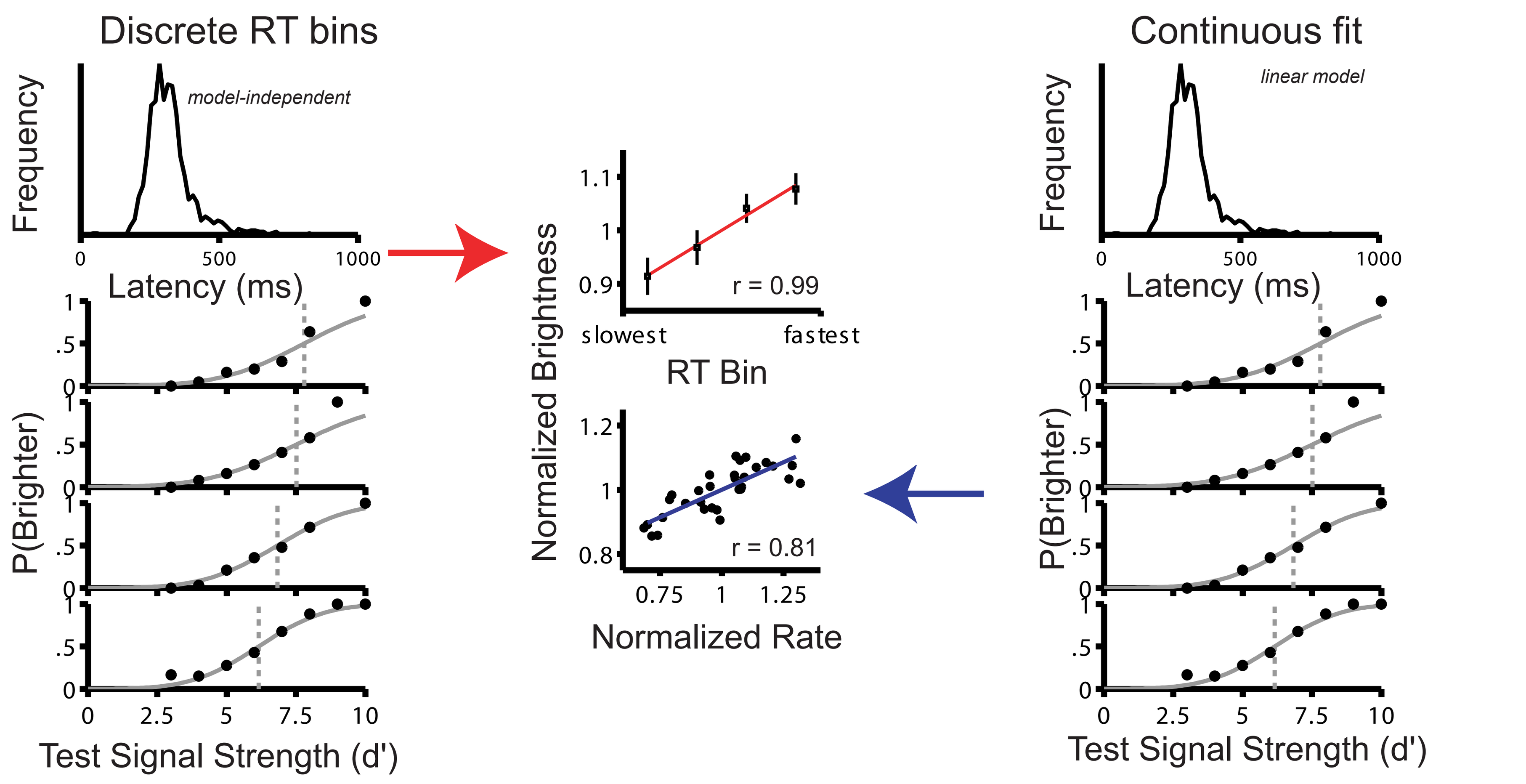


Task Parameters:

Background luminance		37.6 ±8.2 cd/m²
Target eccentricity		6 °
Pedestal diameter		0.6°
Sample image duration		saccade latency
Test image duration		250 ms
Target signal strength	(SNR±SD)	5.5±1
Distractor signal strength	(SNR±SD)	4.2±1
Prior Probability	(5 observers)	0.25, 0.5, and 0.75
Reward Schedule	(3 observers)	0.1, 0.5, and 0.9

Task: On each trial, observers were asked to make a saccade to the brighter of the two choice targets on the **sample image**. We used the saccadic eye movement to trigger a display change from the choice stimuli to the **test image**. Observers then made a perceptual judgment comparing the brightness of the saccade target with the brightness of the test stimulus, which was visible for an interval that was matched to the subject's saccade latency (200-250 ms). By matching the duration of the test interval to the subject's saccade latency, we matched both the eccentricity and the exposure duration of the target and test in the perceptual experiment. Response biases were induced in saccade choices with manipulations of prior probability (Laming, 1969) and the reward schedule (McCarthy and Davison, 1984). For further methodological detail, see Liston and Stone, 2008.

III. RT-triggered psychometric functions



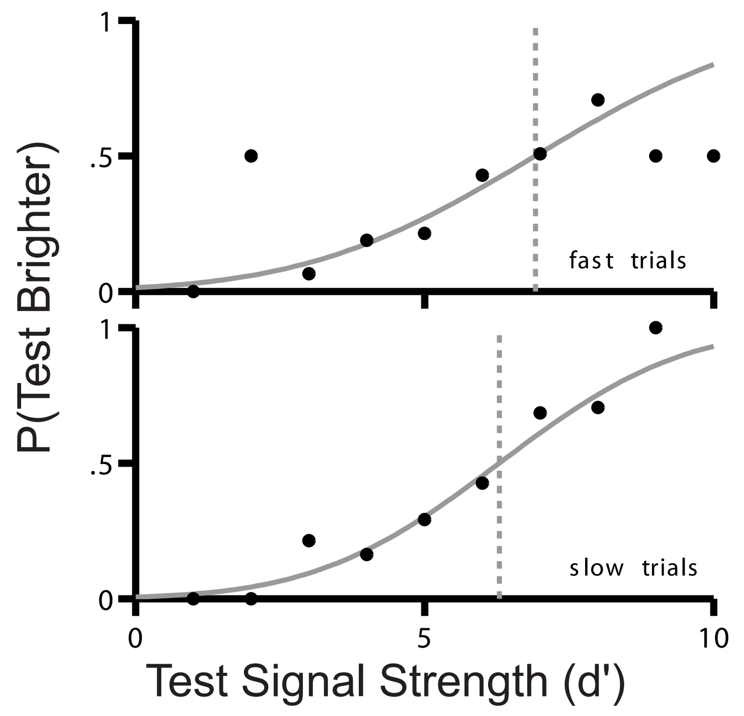
For each subject, we binned the response-time distribution and defined the mean of each psychometric function as perceived brightness.

Perceived brightness is linearly related to normalized response rate ($p<0.0001$, 1-way ANOVA & Pearson's R, $r = 0.81$).

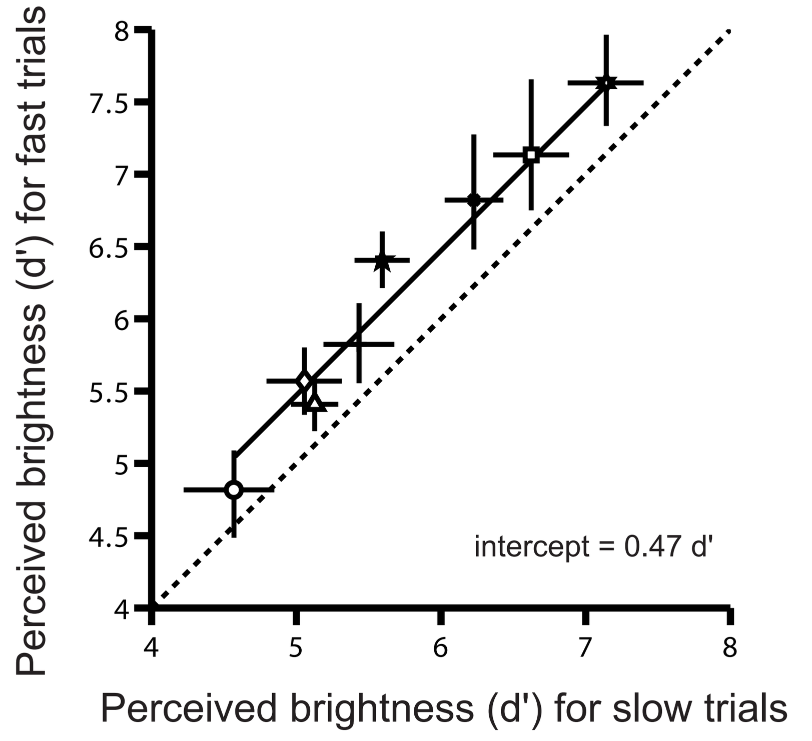
We fit the data for each subject with a continuous linear fit that accounts for response rate.

Although this analysis examines the relationship between perceived brightness and overall system noise in saccadic response rate, it does not distinguish between external (stimulus) and visual (neural) noise.

IV. Controlling for external noise



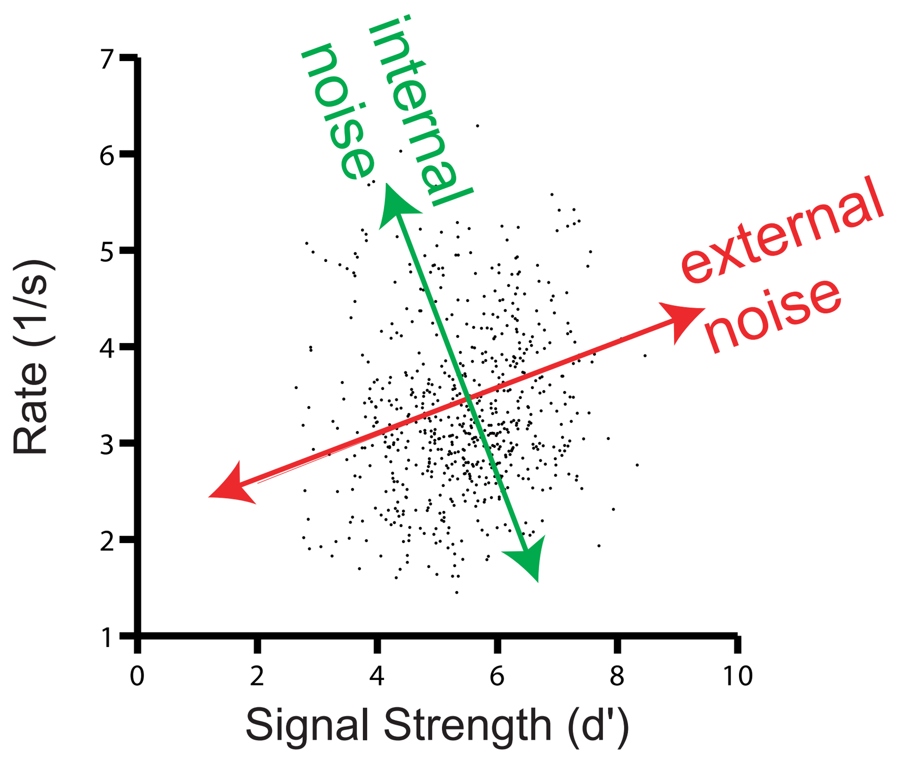
Psychometric functions were constructed for trials designated as either the faster or slower twin.



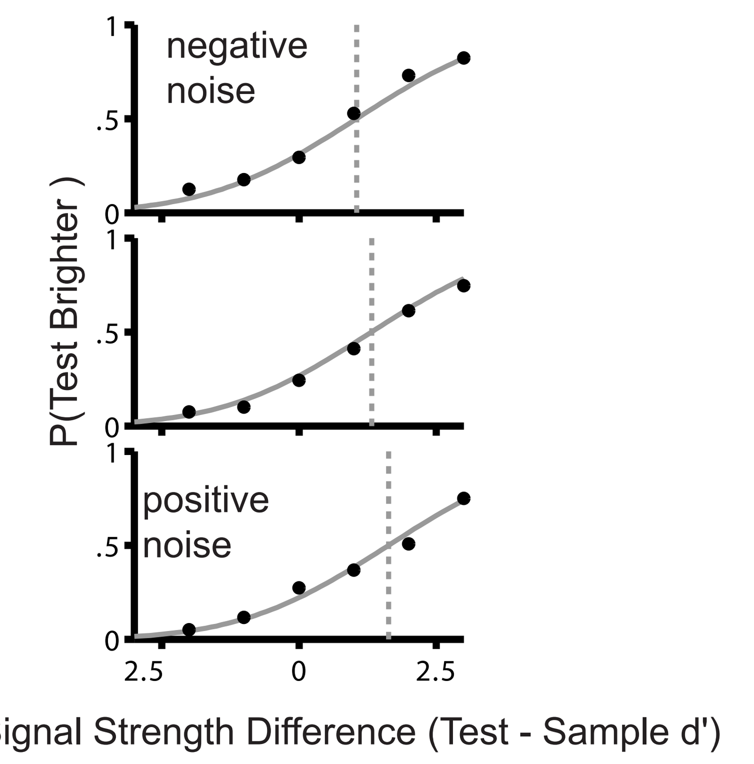
Perceived brightness on fast trials was grater than on slow trials ($p<0.05$ for 7/8 cases, 2-tailed boostrap test).

An analysis using twin presentations of an identical set of stimuli rules out the possibility that the observed correlations arise from variability in physical signal strength.

V. Isolating internal noise



For each subject, we plotted the relationship between response rate and signal strength and defined internal noise as the orthogonal distance between each point and the external noise regression.



We then quantified perceived brightness changes as a function of internal noise, which were always positive (mean: 0.32, SD: 0.19, $p<0.05$ for 8/8 cases, bootstrap test).

VI. Conclusions

Variability in saccadic response rate correlates with perceived brightness, consistent with a shared noisy visual input altering both in parallel.

Coupled trial-by-trial variability in perceived brightness and oculomotor reaction time cannot be accounted for simply by variations in physical signal strength. Thus, in our saccadic 2AFC task, a dominant shared source of early neural visual noise jitters both the percept and oculomotor response in parallel as has been shown with smooth pursuit responses (Stone and Krauzlis, 2003).

The early visual noise source can be modeled as Gaussian variability in the rate of rise of the decision variable (Carpenter, 1981).

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